S-5/PHSH/CC-11/21

TDP (Honours) 5th Semester Exam., 2021

PHYSICS

(Honours)

ELEVENTH PAPER : (CC-11)

Full Marks : 60 *Time* : 3 Hours

The figures in the margin indicate full marks.

SECTION—A

1. Answer *any* **six** of the following questions : 2×6=12

(a) What is an observable?

(b) What does it physically mean by orthonormal condition?

(c) State Larmor's theorem.

(d) Why are symmetric diatomic molecules infrared-inactive?

(e) What do you mean by gyromagnetic ratio?

(f) Name a famous magnetooptical effect.

(g) Write two applications of Raman effect.

(h) What were the new ideas introduced in the vector atom model?

SECTION—B

(There are **four** questions from Question No. 2 to Question No. 5. Answer *either (a) or (b)* from each question.)

Answer the following questions : 3×4=12

2. (a) (i) Show that the momentum operator $\hat{p} = -i\hbar\frac{\partial}{\partial x}$ is Hermitian.

(ii) The wave function in $t = 0$, time is defined as $\psi(x,0)$. If the wave function is normalised, what will be the wave function at any arbitrary time t?

(iii) Calculate the commutator for position and linear momentum operator and hence show that $(xP_x - P_x x)\psi = i\hbar\psi$. 3+4+5=12

[Continued]

(OR)

(b) (i) Explain a wave function. What is its physical significance?

(ii) Explain the formation of Gaussian wave packet and show how it can express the propagation of wave.

(iii) Write the basic postulates of quantum mechanics.

(iv) Normalize the wave function $\psi = e^{ikx}$, $(0 \le x \le 2\pi)$ for the given limit. 2+4+3+3=12

3. (a) (i) For solving the hydrogen atom problem, why spherical polar co-ordinate are used?

(ii) Establish the Schrödinger equation for hydrogen atom in spherical polar co-ordinates. Solve the azimuthal part of the equation. From this, find the allowed values of the magnetic quantum number.

(iii) Find the expectation value of the energy when the state of a harmonic oscillator is described by the wave function

$$\psi(x,t) = \frac{1}{\sqrt{2}}[\psi_0(x,t) + \psi_1(x,t)]$$

where $\psi_0(x,t)$ and $\psi_1(x,t)$ are the wave functions for ground state and first excited state respectively. 2+(3+3)+4=12

[Turn Over]

(OR)

(b) (i) The radial part of the wave function for hydrogen atom in the ground state is given by $R = \frac{2}{a_0^{3/2}} e^{-r/a_0}$. Find the expression for ground state energy of hydrogen atom $(n = 1, l = 0)$.

(ii) A particle is trapped in a one-dimensional infinite potential well following the boundary condition

$v = 0$ for $0 < x < L$
$v = \infty$ for $x < 0$
$v = \infty$ for $x \geq L$

Establish the Schrödinger equation and draw the shape of the wave function for the ground and first excited state.

(iii) For the above condition, find the difference between the energy levels E_1 and E_3. 4+(3+3)+2=12

4. (a) (i) When the X-ray spectra are continuous and when are they discrete?

(ii) Establish Moseley's law from Bohr theory. Write the basic principle behind the Stern-Gerlach experiment and analyse the result of the experiment.

(iii) Find the possible values of j and m_j for the states in which $l = 3$ and $s = \frac{1}{2}$. 3+(3+2+2)+2=12

[Continued]

(OR)

(b) (i) What is space quantisation?

(ii) Considering the electron spin, explain the Zeeman effect in weak magnetic field. With a clear diagram find the number of splitting of energy levels from the state $^2P_{1/2}$ to state $^2S_{1/2}$.

(iii) Write the difference between the first and second order Stark effect. 2+(3+4)+3=12

5. (a) (i) Which of the following elements would you expect to have energy levels divided into singlet and triplet states?
Mg, Ne, Cl, Ca, Cu, Ag, Ba

(ii) According to Pauli's exclusion principle, what is the maximum number of electron in a subshell with a given l?

(iii) What are the possible states for a system of two electrons whose orbital quantum numbers are $l_1 = 1$ and $l_2 = 3$? Consider L-S coupling scheme. (Use spectroscopic notation.)

(iv) What will be the change in the rotational constant B when the hydrogen is replaced by deuterium in the hydrogen molecule? 3+1+5+3=12

[Turn Over]

(OR)

(b) (i) Write the difference between spectra of hydrogen atom and the alkali atomic spectra.

(ii) Explain Raman effect on the basis of quantum theory.

(iii) What do you mean by Stokes and anti-Stokes lines? What are the hot bands in vibrational spectra? 4+4+(2+2)=12

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